International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD)
ISSN (P): 2249-6866; ISSN (E): 2249-7978
Vol. 9, Issue 3, Jun 2019, 9-16

Original Article

BOND SLIP BEHAVIOR OF REINFORCED STEEL AND CONCRETE

V. PREETHA[1], S. NAVANEETHA[2], K. KALAIVANI[3] & V. SENTHILKUMAR[4]

[1]Assistant Professor (Sr.G), Department of Civil Engineering,
Bannari Amman Institute of Technology, Erode, Tamil Nadu, India
[2,3]PG Students, Department of Civil Engineering,
Bannari Amman Institute of Technology, Erode, Tamil Nadu, India
[4]Associate Professor, Department of Civil Engineering,
Bannari Amman Institute of Technology, Erode, Tamil Nadu, India

ABSTRACT

The performance of bond behavior between steel and concrete in reinforced concrete structure is a major part in load transfer mechanism. The transfer of stress between reinforcement and concrete in the longitudinal direction of the bars is known to be bond. Bond strength is imperative in reinforced concrete, which means that load transfer and the structural behavior is achieved by the combination of two materials. Sufficient bond strength ensures that there is little or no slip between steel and concrete and helps in the safe transfer of stress between them. Anchorage of reinforcement depends on the bond between steel and concrete, crack width and crack spacing. Stiffness, deformation and dynamic behavior are also a function of bond. In this article the experimental investigations on bond strength is studied for M20 grade of concrete. Pull out test is carried out using universal testing machine, the load at a relative movement (slip) between steel and concrete at the free end of the bar is manipulated. The main objective of the study is to come out with a relationship between bond strength and different influencing factors affecting the bond strength as per IS 2770-1967.

KEYWORDS: *Concrete, Reinforcement, Bond Strength & Bond Stress*

Received: Mar 02, 2019; **Accepted:** Mar 22, 2019; **Published:** Apr 11, 2019; **Paper Id.:** IJCSEIERDJUN20192

INTRODUCTION

The reinforced concrete consists of both concrete and steel to take care of compression and ductile in tension. To maintain the composite action transfer of load between the concrete and steel is ensured by means of bond stress [1]. For reinforced concrete structures the bond stress capacity of the element exceeds the demand and there by relatively little slip between the steel and the surrounding concrete. Plain reinforced bar without lugs on the surface exhibit more deformations and therefore cannot transfer proper bond forces by mechanical interlocking [4]. But the bond is transferred by means of adhesion between the concrete and the reinforcing bar before slip occurs. The wedging action that break the concrete upon slip. Usually, bond behavior is predicted by bond stress versus slip relationship by experimental data using pull out study [6]. The pullout test predicts the exact failure mechanism of bond and therefore allows for accurate assessment of bond capacity. Here the experimental work is done to analyze the depth of embedment and variable diameter of reinforced bar in to the concrete surface. It is necessary to institute accurate bond stress-slip relationship in a reinforced concrete member, which is usually based on depth of embedment and axial tension force at the cracking position [18].

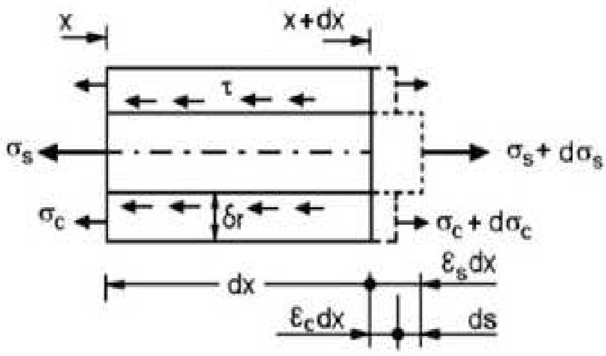

Figure 1: Steel-Concrete Bonding Stress

BEHAVIOR OF BOND BETWEEN REINFORCED STEEL AND CONCRETE

The bond stress-slip relationship is expressed by the mechanism of bonding obtained from pull-out tests as shown in Figure 2. The factors that define the bond strength are comprised of an adhesive bond, a frictional bond, and a shear bond. In case of deformed bars, the mechanical interlocking action is governed based on bond resistance capacity. The adhesion is less important in magnitude and resists only small stress. Friction bond is a mechanical interlock between irregularities of steel surface and concrete, with magnitude superior than adhesion and arises after the adhesion is broken. After losing adhesive and frictional bond mechanisms tension is transferred by bearing of bar deformation.

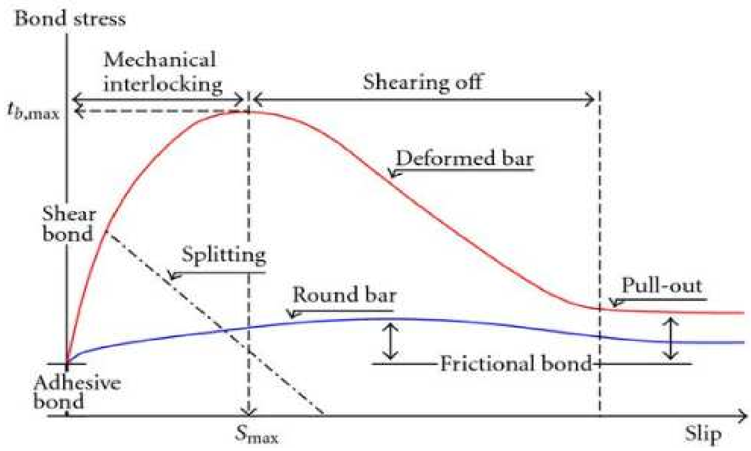

Figure 2: Bond Stress-Slip Relationship

EXPERIMENTAL INVESTIGATION

Test Programme

Material Properties

Portland cement, Fine aggregate (River sand), Coarse aggregate (Broken stones of 20 mm in size), Deformed steel bars were used in this experimental program. For this test, specimen of size 150 mm x 150 mm x 150 mm with high yield deformed bar is placed at the centre of cube and 150 mm embedded in concrete. The grade of concrete adopted is of M20 of which the compressive strength is 18.9MPa. The results for the 28-day average compressive strength is shown in Table 1 along with the mechanical properties of deformed bar used in all specimens.

Specimen Preparation

A total of 30 pull-out specimens were casted. Deformed reinforcing bars having nominal diameters of 10, 12 and 16mm were then embedded in each of the concrete mixes. Each concrete mix are comprised of 5 specimens each belonging to the different diameters of rebars. The details of the pull-out specimens are shown in Figure 3.The cross-section of the pull-out specimens for cube is 150 mm x 150 mm x150mm. The steel rebar was embedded in the centre of concrete with 400 mm of the reinforcement bar length projecting out on one end and 10 mm of the reinforcement bar on the other end. All pullout specimens were tested at the end of 28 days after casting. The experimental work has been done to study the influence of the main parameters on bond strength between steel bars and concrete, embedded length of rebar, concrete strength and rebar diameter.

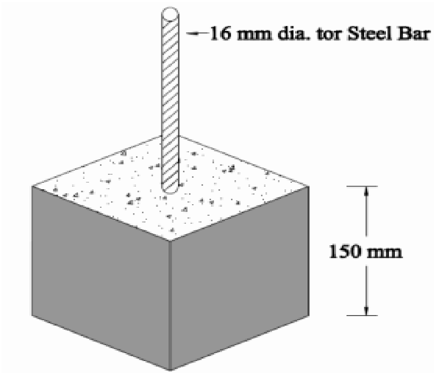

Figure 3: Steel-Concrete Bonding

Test Set-Up

The pullout tests were conducted in a universal testing machine as IS 2770-1 a procedure similar to ASTMC 234 as shown in Figure 4. Since slipping of the deformed bars at the maximum loading is small, LVDT is installed on the free end and the loading end to measure the rebar's displacements. The test must be ceased while the displacement of the free end exceeded 2mm [10]. The value of average nominal bond stress-strain can be calculated as the normal force F which is divided by the surface area of the rebar embedded in the concrete. For a circular cross section of the reinforcing bar, in which the diameter is d, the average bond strength can be calculated by the using the formula,

$$\tau_{av} = \frac{F}{(\pi.d.L)}$$

Where L is the length of embedment. The maximum average bond stress of each specimen can be calculated from while the maximum tensile load occurs.

Figure 4: Testing of Specimens

FAILURE PATTERN OF SPECIMENS

The Specimens are tested in the universal testing machine and the bond strength is determined using the pull-out test. The cube with different diameter reinforced bar at the centre is tested. The steel is strong in tensile strength and weak in compression but the concrete is strong in compression and weak in tensile strength. In pull-out test the tensile force is acted in the rod within the cube specimens, the bond between the steel and concrete gets fails due to tensile strength. The bonding between the two materials varies which depends mainly on the diameter of the bar.

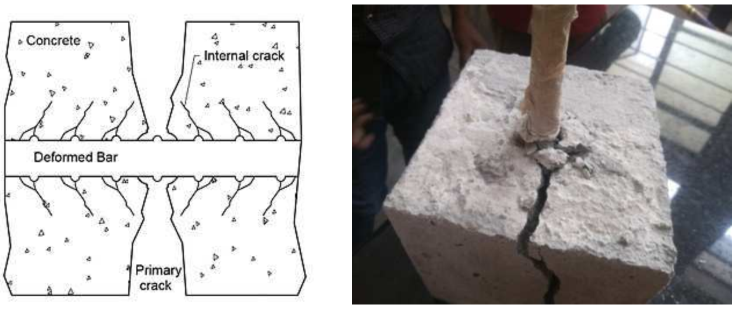

Figure 5: Cracking Pattern

Figure 6: Steel-Concrete Failure

NUMERICAL SIMULATION USING ANSYS

ANSYS is an engineering simulation software used for a variety of engineering applications. ANSYS is capable of both pre and post-processing. The experimental analysis is verified using ANSYS software. The ultimate load obtained from the experimental investigation taken as the force value for analyzing the cube with rod in ANSYS analysis.

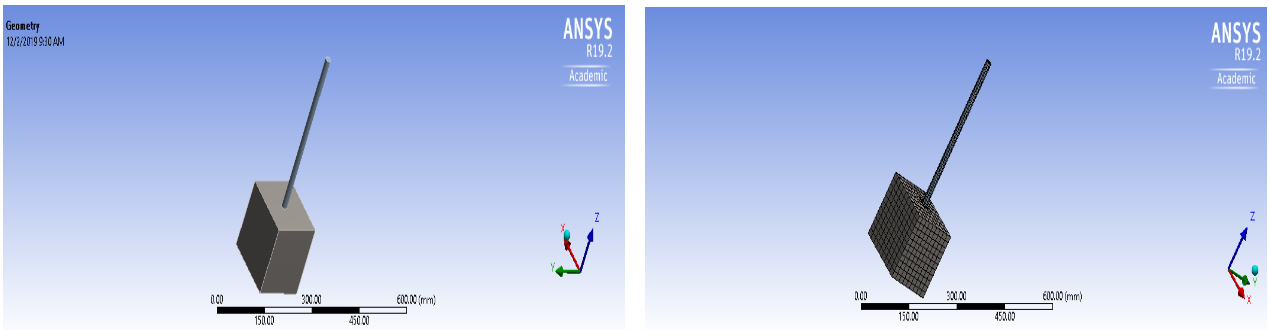

Figure 7: Modelling of a Cube with a Rod

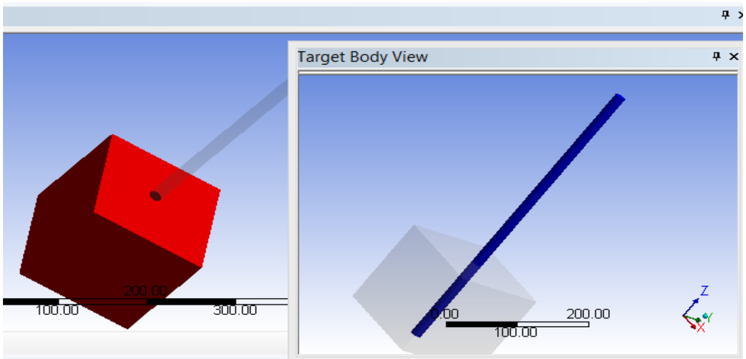

Figure 8: Contact Bonding Between Steel and Concrete

RESULTS AND DISCUSSIONS

The specimens are tested for different diameter of reinforced bar are tabulated .The results of the pull-out tests in terms of ultimate load, bond strength, slip at ultimate load and its failure method are presented in table. The failure deformation pattern of the specimen are also compared with experimental data as shown in figure 11.

Table 1: Experimental Results

Specimen	Specimen name	Ultimate Load (kN)	Total Slip (mm)	Load @ 0.025mm slip(kN)	Load @ 0.25mm slip(kN)
Cube 150x150x150 with 10mm rod, Length of Embedment-150mm	CU101	83.95	1.2	49.34	78.51
	CU102	92.25	1.5	52.5	88.42
	CU103	85.15	1.3	51.35	74.56
Cube 150x150x150 with 12mm rod Length of Embedment-150mm	CU121	117.52	2.1	79.34	78.51
	CU122	106.58	2.2	72.51	98.42
	CU123	121.54	2.4	71.35	94.56
Cube 150x150x150 with 16mm rod, Length of Embedment-150mm	CU161	126.85	2.8	94.34	96.51
	CU162	128.94	3.01	98.5	101.42
	CU163	129.58	2.2	91.35	94.56

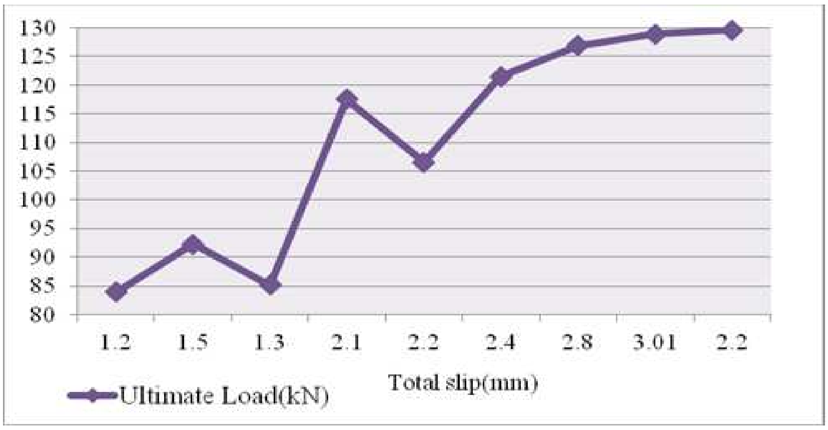

Figure 9: Load Vs Total Slip

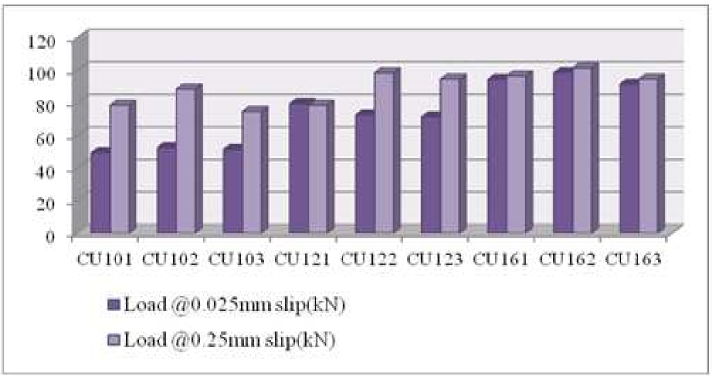

Figure 10: Load vs Slip @ 0.025 & 0.25mm

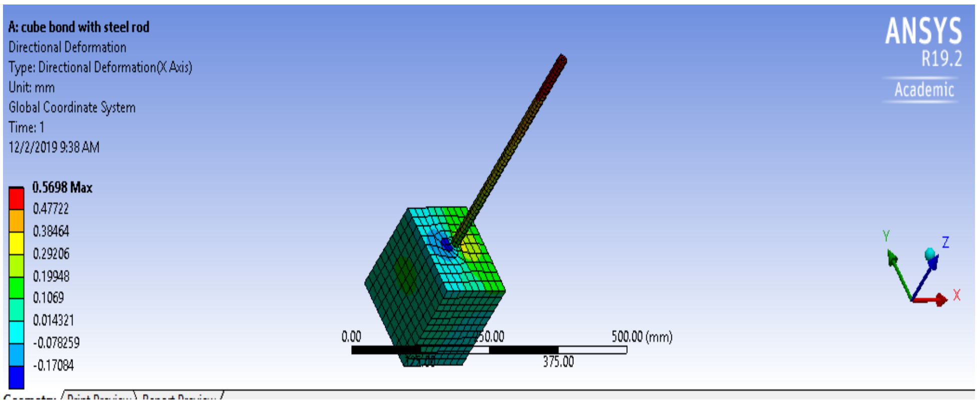

Figure 11: Deformation of Specimen

CONCLUSIONS

For the specimens studied in this investigation, concrete possesses bond strength almost good with the steel. Overall behavior of Load vs Slip and Bond stress vs. Slip of concrete is calculated. The combined effects of crack widths and bar diameters on the bond strength have shown, however the ductility of bond specimens decreased as the diameter increased. The ultimate strength (kN) and Total slip (mm) of steel-concrete bonding gets simultaneously increased when the diameter of the bar increased. In comparing the values of load at 0.025mm and load at 0.25mm slip(kN),the ultimate load(kN) at 0.25mm is high. Depending upon the depth of embedment of reinforcing bar in the concrete, the ultimate strength of the specimen is varied.

REFERENCES

1. *Xiao Liang and Sri Sritharan, An Investigation of Bond-Slip Behavior of Reinforcing Steel Subjected To Inelastic Strains, Tenth U.S. National Conference on Earthquake Engineering Frontiers of Earthquake Engineering, July 21-25, 2014.*
2. *Giuseppe Campione, Calogero Cucchiara, Lidia La Mendola and Maurizio Papia, Experimental Investigation on Local Bond-Slip Behaviour in Light Weight Fiber Reinforced Concrete Under Cyclic Actions, 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada, August 1-6, 2004, Paper No. 2087.*
3. *Sungnam Hong and Sun-Kyu Park, Uniaxial Bond Stress-Slip Relationship of Reinforcing Bars in Concrete, Hindawi Publishing Corporation Advances in Materials Science and Engineering, Volume 2012, Article ID 328570, 12 pages, doi:10.1155/2012/328570.*
4. *Guohua Xing, Cheng Zhou, Tao Wu, and Boquan Liu, Experimental Study on Bond Behavior between Plain Reinforcing Bars and Concrete, Hindawi Publishing Corporation Advances in Materials Science and Engineering, Volume 2015, Article ID 604280, 9 pages,* http://dx.doi.org/10.1155/2015/604280.
5. *Mohammed Sonebi, Richard Davidson, and David Cleland, Bond between Reinforcement and Concrete – Influence of Steel Corrosion, DBMC International Conference on Durability of Building Materials and Components PORTO- PORTUGAL, April 12th-15th, 2011.*
6. *Reddy, M. V. S., Mrudula, D., Seshalalitha, M., & Hariprasad, P. (2015). The effect of Crushed Rock Powder and Super plasticizer on the fresh and hardened properties of M30 grade Concrete. International Journal of Civil, Structural, Environmental & Infrastructure (IJCSEIERD), 5, 25-30.*
7. *S. P. Tastani, MSc, PhD Candidate and S. J. Pantazopoulou, Experimental Evaluation of The Direct Tension -Pullout Bond Test, "Bond in Concrete – from research to standards" 2002, Budapest.*
8. *Alaa Hussein Al-Zuhair, Wjdan Dhalf Sahi Al- Fatiawi, Bond-Slip Relationship of Reinforcing Steel Bars Embedded in Concrete, Ministry of Higher Education and Scientific Research, 5-7 April 2009, Volume 1.*
9. *P. Máca, E. Panteki& M. Curbach, Bond Stress-Slip Behaviour of Concrete and Steel Under High-Loading Rates, The 14th International Conference on Structures Under Shock and Impact (SUSI 2016), Vol. 4, No. 3 (2016), ISSN: 2046-0554.*
10. *B. Nithya, P. Srinivasan, M. Suji, and P. Lokeshkumar, A Comparative Study on Bond Strength of Reinforcing Steel in Bottom Ash Concrete and Controlled Concrete, International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization), May 2015, Vol. 4, Special Issue 6.*
11. *Ji-Hua Zhu1, Liangliang Wei, Miaochang Zhu, Weiwen Li and Feng Xing, Experimental Study of Bond Behavior on Aluminum Alloy Plate-to-Concrete Interface, Applied Mechanics and Materials, January 2014, DOI: 10.4028/www.scientific.net/AMM.501-504.805.*
12. *J. Shafaie, A. Hosseini and M. S. Marefat, 3D Finite Element Modelling of Bond-Slip Between Rebar and Concrete in Pull-Out Test, 3rd International Conference on Concrete & Development.*
13. *Donna C. Day, Mariangelica Carrasquillo, Charles A. Weiss, Jr., Melvin C. Sykes, Earl H. Baugher, Jr., and Philip G. Malone, Innovative Approaches To Improving The Bond Between Concrete and Steel Surfaces, USAE Engineer Research and Development Center, Vicksburg, MS 39180.*
14. *Garg, C., & Jain, A. (2014). Green concrete: Efficient & eco-friendly construction materials. International journal of research in engineering and technology, 2(2), 259-264.*

15. *K. Lundgren, Effect of corrosion on the bond between steel and concrete: an overview, Magazine of Concrete Research, 2007, 59, No. 6, August, 447–461, doi: 10.1680/macr.2007.59.6.447.*

16. *U. M. Mahran, Theoretical Study For Bond Between Reinforcement Steel And Concrete, International Journal of Sciences: Basic and Applied Research (IJSBAR), ISSN 2307-4531, (2013) Volume 12, No 1, pp 93-102.*

17. *Uttam B. Kalwane, Ajay G. Dahake, Vasudev R. Upadhye, Effect of Polymer Modified Steel Fiber Reinforced Concrete on Bond Strength, Journal of Experimental & Applied Mechanics, ISSN: 2230-9845(online), ISSN: 2321-516X(print) Volume 6, Issue 2.*

18. *Kazim Turk, Sinan Caliskan, and M. Sukru Yildirim, Influence of loading condition and reinforcement size on the concrete/reinforcement bond strength, Structural Engineering and Mechanics, Vol. 19, No. 3 (2005) 337-346.*

19. *Kai Xu, Changchun Ren, Qingshan Deng, Qingping Jin, and Xuemin Chen, Real-Time Monitoring of Bond Slip between GFRP Bar and Concrete Structure Using Piezoceramic Transducer-Enabled Active Sensing, Sensors 2018, 18, 2653; 13 August 2018 doi:10.3390/s18082653.*

20. *Alam, M., Singh, G., Bahaa, B. E. S. H., & Sahar, M. (2013). Acceptability of demolished concrete waste aggregate in making high strength self-compacting concrete. International Journal of Civil Engineering (IJCE), 2.*

21. *Sungnam Hong and Sun-Kyu Park, Uniaxial Bond Stress-Slip Relationship of Reinforcing Bars in Concrete, Hindawi Publishing Corporation Advances in Materials Science and Engineering, 13 February 2012, Volume 2012, Article ID 328570, 12 pages, doi:10.1155/2012/328570.*